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ESTHETIC POSTERIOR STAINLESS STEEL CROWNS AND THEIR RELATIVE
SHEAR STRENGTHS

A Thesis submitted in partial fulfillment of the requirements for the degree of Master of
Science in Dentistry at Virginia Commonwealth University.

by

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Abstract

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By Lonny D. Carmichael, DDS

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Science in Dentistry at Virginia Commonwealth University.

Virginia Commonwealth University, 2008

Major Director: Tegwyn H. Brickhouse, D.D.S., Ph.D
Assistant Professor, Department of Pediatric Dentistry

Purpose: The purpose of this study was to evaluate esthetic posterior stainless steel crowns (EP-SSC) and compare their relative shear strengths.

Methods: Sixty EP-SSC were compared. 15 crowns from NuSmile® Primary Crowns, Kinder Krowns, and Dental Innovators 1UP and EC Crowns were studied. The crowns were cemented to a typodont tooth then thermally cycled in water baths to simulate oral conditions. Shear strengths were evaluated by subjecting these crowns to simulated forces of occlusion.

Results: The force required to cause shearing of the esthetic facings was statistically significant. With the 1UP crown being significantly weaker than the other crowns tested.

Conclusion: The 1 UP crowns failed at lower levels of force than the other types of EP-SSC. The shear strengths for the three other crown types were not statistically different from each other. The esthetic facings do not likely fail from the single point load of a child's bite.

Introduction

According to the first-ever United States Surgeon General's report on oral health in America published in May 2000, dental caries is the single most common chronic childhood disease. Over fifty-percent of 5-9 year old children have at least one cavity or filling with this proportion increasing into adolescence.¹ It is estimated that children miss 52 million hours of school each year due to tooth decay and other dental problems.^{1,2} Children from lower socioeconomic groups are at greatest risk for decay with children of Mexican-American ethnicity having the greatest prevalence of caries.³ An estimated 40% of children aged two to eight years of age have experienced dental caries in their primary teeth.⁴ In permanent teeth, 24 percent of children ages 5-17 years of age represent as much as 80 percent of the caries prevalent in this age group.⁵ In 2004 an excess of \$81 Billion was spent on dental services. It is projected this number will increase to more than \$116 Billion in 2010 and \$147 billion in 2014.⁶ In 1996, dental expenditures for children was in excess of \$12 billion, 27.8% of the total expenditures of \$43.1 billion for that year.⁷ This same year, the average real expenditures per child age 2-17 was \$498.57.⁸

Furthermore, dental caries is not a self limiting disease, nor amenable to treatment with a simple course of antibiotics, like an ear infection.⁹ Surgical intervention is the necessary treatment for the restoration of dental caries. Many practitioners feel the primary stainless steel crown is one of the most definitive, reliable, and long lasting

restoration for primary teeth. Preformed stainless steel crowns were introduced to dentistry by Humphrey in 1950. Since that time, they have become an invaluable restorative material in the treatment of badly broken-down primary teeth. They are generally considered superior to large multi-surface amalgam restorations and have longer clinical lifespan than two or three surface amalgam restorations.¹⁰ Stainless steel crowns (SSC) are typically used to restore teeth that have extensive or multiple carious lesions, are hypoplastic, have hereditary anomalies, and have been endodontically treated.¹¹ Recently, trends in esthetics and patient demand have caused practitioners to seek more esthetic restorations than the traditional stainless steel crown. During the 1990s esthetic anterior stainless steel crowns with composite veneered facings entered the marketplace and received a high parental satisfaction rate.¹² Great effort has been put into finding an esthetic solution for primary posterior teeth. In the last few years, various esthetic posterior stainless steel crowns (EP-SSC) for primary teeth have appeared on the market as well as the use of strip crown forms for posterior primary teeth. A long term clinical study of the EP-SSC found that after a 4 year period, all of the crowns studied exhibited some type of failure of the esthetic facing.¹³ A clinical evaluation which compared EP-SSC with open face posterior stainless steel crowns showed that the open-face crowns had a higher clinical success rate after 18 months. However, the EP-SSC were found to have a more esthetic result than the open-face SSC for primary posterior teeth. The less esthetic outcome of the open-face SSC was thought to have been from contamination with blood and saliva.¹⁴

Manufacturers have the following recommendations for the use of EP-SSC: 1) prepare the tooth as for a standard stainless steel crown, bearing in mind that greater circumferential and occlusal reduction will be required, 2) do not excessively force the crown onto the tooth. Find the crown size that is the closest fit and refine the preparation of the tooth to fit the crown. A properly fitted crown should have a passive fit, 3) crimp the lingual aspect of the crown slightly, or contour the mesial and distal aspects of the crown slightly. Excessive flexure of the metal structure underneath the composite, however, may cause fractures in the composite, 4) the length of the crown may be altered by trimming the gingival margins with a diamond disc, however, this is not likely to be necessary if the tooth has been adequately prepared subgingivally, and 5) The occlusion may be refined by shaping with a fine finishing bur.¹⁵ The crimping of veneered EP-SSCs is limited; certain brands allow crimping only on the lingual surface and others may be crimped all the way around.¹⁶ Over the last decade it has been found that stainless steel crowns are best bonded into place with resin-modified glass ionomer luting cement. Such cements are biocompatible, form a chemical bond to tooth structure and have high physical strengths and insolubility in the mouth. Properly adapted stainless steel crown forms that are cemented with resin-modified glass ionomer cement generally do not detach from the tooth.^{17,18}

Specific Aims

The purpose of this study was to evaluate various pediatric esthetic posterior stainless steel crowns (EP-SSC's) by subjecting them to simulated oral conditions and evaluating their respective shear strengths.

Material and Methods

Sixty esthetic posterior stainless steel crowns were used for testing. They consisted of 15 stainless steel crowns from each of four different manufacturers; Kinder Krown (KK), Nu Smile® Primary Crowns (NU), Dental Innovators 1 Up (UP) and “EC” or Esthetic Crimpable crowns (EC). A lower mandibular first molar was selected as the type of crown to be tested. This was due to the common restoration of primary 1st molars with stainless steel crowns. Primary 1st molars are also in highly visible areas of the mouth. It has also been shown that esthetic mandibular posterior crowns have a higher rate of failure than their maxillary counterparts.¹⁹

A lower left primary first molar typodont tooth was prepared for each crown. Each tooth was prepared for an ideal SSC preparation with greater reduction circumferentially and occlusally to accommodate the manufacturer recommendations for the EP-SSC. These crowns were test fit to confirm the proper adaptation to the prepared tooth. It is recommended by the manufacturers that EP-SSC have a passive fit. Extreme stresses during seating or cementation can cause premature failure of the esthetic facing. The crowns were then cemented with Fuji Glass Ionomer cement. Excess cement was removed and the cement was allowed to set for 24 hours. All crowns were then thermally cycled in water to simulate the changing temperature extremes found in oral conditions. Hot and cold water baths were used. The hot water bath was heated to and maintained at 55° C.

The cold water bath was maintained at 4° C with the constant addition of ice. The crowns were cycled from hot water to cold water for a total of 500 cycles. A cycle consisted of the crowns being in each of the hot and cold water baths including the time the lever arm took to transport between each bath, which was approximately 15 seconds. The duration of each cycle was one minute. Mastication forces were simulated and measured to determine the maximum force of mastication that is required to fracture the esthetic facing of the stainless steel crowns. This force was determined by taking the previously prepared crowns and subjecting these to a point load of continually increasing force until failure of the facing was observed. A testing jig was made by using a 3 point mounting block with a round canister that contained orthodontic resin adapted to hold the tooth securely during testing. Fracture strengths were evaluated by subjecting these crowns to simulated forces of mastication with an Instron machine (Instron, Canton, MA). Once the tooth was secured in the mounting jig, a 3mm ball bearing in the Instron was placed on the occlusal surface at an angle perpendicular to the occlusal surface. The Instron recording mechanism was then zeroed and readied for recording. Testing commenced as force was consistently increased using the Instron. The ball bearing was advanced with a constant speed of .2 in/min and the continually escalating forces were recorded. Once failure of the facing had occurred the testing was stopped, the ball bearing was backed away from the tooth, and the maximal force that had been exerted on the crown to cause failure of the esthetic facing was recorded. This process was repeated for all crowns in the study. The testing preparation and procedures have been summarized in Table 1.

Results

After the in-mouth simulation and before the physical testing of the crowns, the EC crown was observed to exhibit micro crack formation that began at the interface of the crown and the esthetic material and continued occlusally. Microscopic examination of the crown surface at 10X magnification confirmed this finding. When these crowns were loaded during physical testing the micro crack was observed propagating from the original micro crack toward the simulated force until a point loading failure of the facing occurred. In every instance the failure of the facing was coincident with the location of the existing crack. No other crowns were observed to have micro crack formation after the in mouth simulation portion of the experiment when observed under the microscope.

Table 2 and figure 1 display the pounds in force that were required to cause shearing, distortion, or dislocation the esthetic veneering from the different types of crowns. This table shows the mean values of force in pounds with their standard deviations required to cause shearing of the esthetic facings follows: UP 91.2 ± 25.24 , EC 163.3 ± 86.81 , KK 166.7 ± 17.89 , NU 169.7 ± 53.80 . It was observed that the shearing of the esthetic facings occurred with a skewed nature having unequal variance with relation to the standard deviation for each crown type. To account for the varied distribution of forces the shear values were log transformed and analyzed via ANOVA analysis. The ANOVA test on the log transformed values revealed statistical significance ($F(2,56)=12$,

p<0.0001.) The estimated means of the log transformed values were analyzed with their 95% confidence levels. Tukey's HSD found the 1 UP crown was significantly weaker than all of the other three brands and that the other brands were not significantly different from one another with respect to the forces required to cause shearing of the esthetic facings. The estimated geometric means of the four groups are shown in Table 3 and Figure 2. The 95th percentile force may be estimated using Weibul survival analysis. These estimated values, and their confidence intervals, are shown in the lower portion of Table 3.

Discussion

For the purposes of this study, “shear strength failure” was defined as the point where all or a portion of the esthetic facing was dislodged due to the force from the Instron machine. In the case of the EC crown, the shearing point was the point at which loading of the esthetic material caused plastic distortion until an obviously large crack had occurred and a complete loss of the esthetic facing was eminent.

All of the crowns exhibited unique shear strength failures in response to the physical testing with the Instron. This is likely due to the various methods of bonding the esthetic facing to the underlying crown employed by each manufacturer. This study confirms previous findings that the practitioner is left with a unique “problem” after failure of the esthetic facing occurs. The underlying crowns remain intact with the failure of the crown being largely esthetic in nature.²⁰ Both the EC and the UP crown from Dental Innovators had the esthetic facings anchored to a wire mesh framework that was also secured to the metal crown surface. The shearing of the EC crowns was characterized by a plastic deformation of the esthetic material followed by subsequent cracking and a failure to endure great loading by the Instron. It is important to note that not all of the EC crowns experienced a veneer failure with complete loss of the esthetic facing. However, for the purposes of this study the deformation and subsequent cracking of the EC crown material was still considered a failure as complete dislodgement of the esthetic material was

eminent. These esthetic veneers were observed to be of a plastic material that is capable of a malleable response under loading. This property of the EC crown may provide for greater durability in response to traumatic forces that are applied to the veneer. The other 3 types of crowns displayed a mixed failure of adhesion and cohesion.²¹ The UP crowns were observed to have a failure that was characterized by a knife-edge fracture of the facing with the esthetic material partially shearing off in piece from the failure point apically. Neither the NU nor KK type crowns used wire mesh type adhesion. The NU crown has a metal crown surface consistent with one that would have been micro etched for increased retention of the esthetic material that then bonded to the metal surfaces. The KK uses the mechanical retention of perforations in the occlusal surface with esthetic material flowed into the perforations then bonded to the metal surface. Failure of the esthetic facings with both the KK and NU crowns would occur at the point of loading with spalling of the esthetic facing occurring from this point apically, leaving a large portion of the esthetic facing intact and exposing the metal crown underneath. With both KK and NU types there was esthetic material remaining around the outline of failure point.

A recent study analyzing bite forces in children age 7-13 found that the average child was able to exhibit a maximum biting force of 382.2 N or 86.8 lbs. of force.²² These findings help to illustrate the clinical relevance of this study. The lowest mean force required to cause shearing of the esthetic facing was with the UP crowns with a mean force of 91.2 lbs \pm 25.24, a mean force being higher than the average child can exert. Looking at the data points for each crown tested, 3 of the four types of crowns had crowns with at least one crown whose esthetic facing sheared within this biting force range. NU 1/15 or

6% of crown at 83 lbs, EC 2/15 or 13% crowns 86 and 73, and UP with 5/15 or 33% crowns at 65, 85, 74, 36, and 83 respectively. There were no KK crowns that fell in this range. With the majority of crowns tested having a mean force required to cause shearing higher than that of the average child, it is unlikely that shearing of the esthetic facings is due to a single event. The findings of this study support that clinical failures of the esthetic facings of the EP-SSC are most likely due to a combination of shearing forces and fatigue. This also speaks to a limitation of the current study due to the single nature of the force exerted by the Instron, there is no consideration given to shearing due to fatigue. Further investigation is required to determine the actual clinical cause of failure of these esthetic facings.

Conclusion

This study found the 1UP crowns failed when subjected to a lower mean force being exerted on the esthetic facing than the other types EP-SSC tested with statistical significance. NU, KK, and EC Crown failure points were not statistically different from each other. It is unlikely that the esthetic facings will fail as the result of a single point load, with respect to the average maximal biting force of a child.

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Literature Cited

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Table 1: Testing Procedures

<i>In-mouth simulation</i>
a. Prepare a typodont tooth for the EPSSC
b. Cement crown to tooth
c. Temperature cycling from 4°C to 55°C
d. Time of temperature cycle (60sec)
<i>Physical Testing Procedures</i>
a. Mount cycled crowns to perform a failure test
b. Load crown at .02"/min
c. Observe load curve/failure load
d. Observe tested sample under microscope (before and after fracture testing)

Table 2: Observed Force

Make	n	Pounds	
		Mean	SD
1-UP	15	91.2	25.24
EC	15	163.3	86.81
Kinderkrown	15	166.7	17.89
NuSmile	15	169.7	53.80

Table 3: Estimated Means for Each Group

Make	Pounds		
	LS Mean	95% CI	
1-UP	87.5	73.62	104.02
EC	145.7	122.57	173.19
Kinderkrown	165.8	139.49	197.09
NuSmile	161.6	135.98	192.14

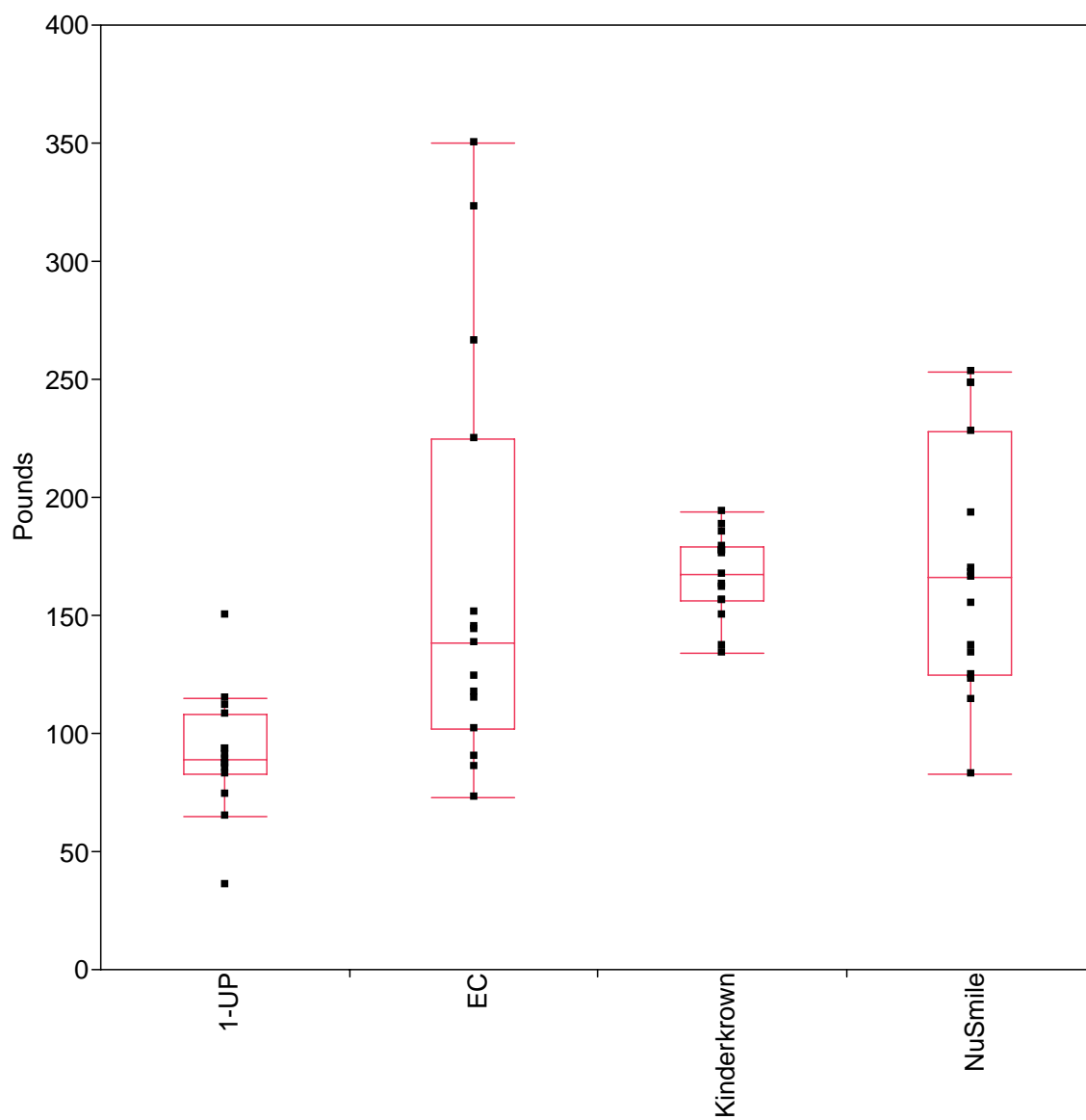


Figure 1: Observed Force

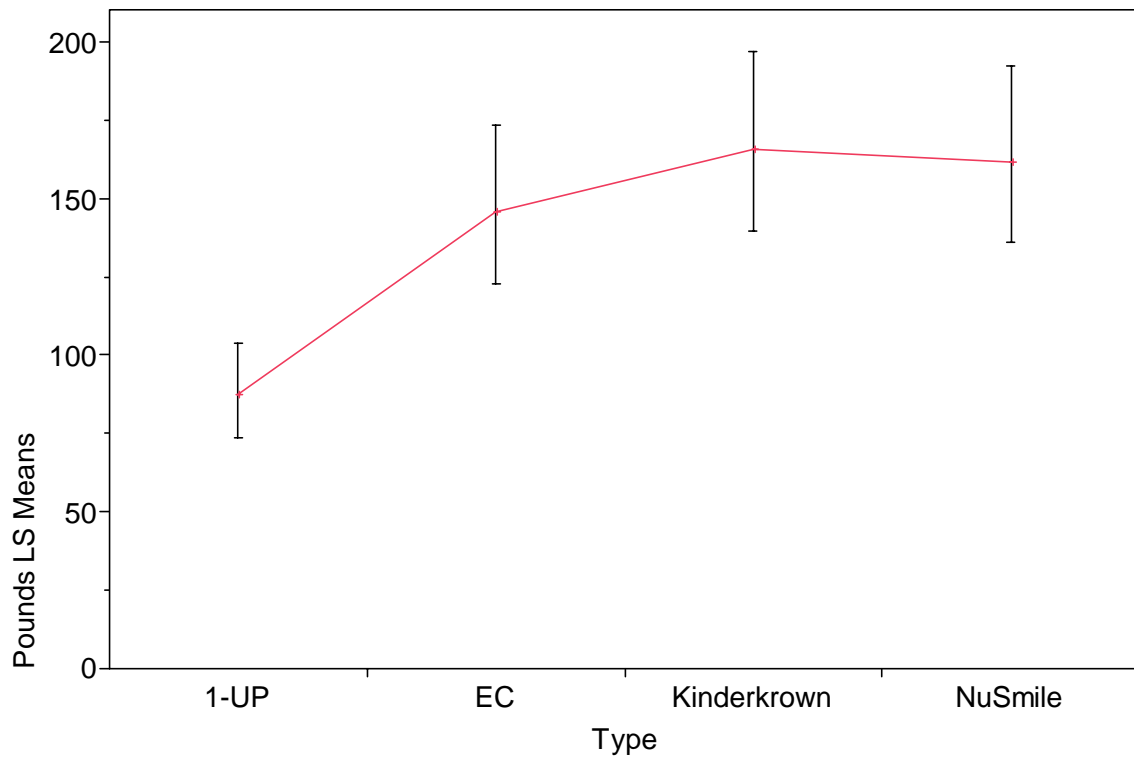


Figure 2: Estimated Means and 95% Confidence Intervals

VITA

Lonny D. Carmichael was born September 19, 1977 in Phoenix, Az. He graduated from Buckeye Union High School in 1996. He graduated with distinction from Mesa Community College in 2000, then received his Bachelor of Science degree in Medical Sciences from the University of Colorado in 2002. Dr. Carmichael graduated from the University Of Colorado School Of Dentistry in 2006.